INDOOR AIR QUALITY ASSESSMENT

James F. Peebles Elementary School Annex
70 Trowbridge Road
Bourne, Massachusetts

Prepared by:
Massachusetts Department of Public Health
Center for Environmental Health
Bureau of Environmental Health Assessment
Emergency Response/Indoor Air Quality Program
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Background/Introduction

At the request of a parent, the Massachusetts Department of Public Health (MDPH), Bureau of Environmental Health Assessment (BEHA) was asked to provide assistance and consultation regarding indoor air quality at the Peebles Elementary School (PES), 70 Trowbridge Road, Bourne, Massachusetts. On February 26, 2004, Cory Holmes, an Environmental Analyst in the Emergency Response/Indoor Air Quality (ER/IAQ) Program, conducted an indoor air quality assessment. Mr. Holmes was accompanied by Heather Gallant, Health Inspector, Bourne Board of Health. Concerns about possible mold growth resulting from a frozen heating coil rupturing in a second floor unit ventilator (univent) in the PES Annex (the annex) prompted the assessment.

The PES is a two-story, red brick building constructed in 1950 (1950 wing). The annex is a two-story addition built in 1955. A corridor connects the two buildings. The 1950 wing and the annex have heating, ventilating and air-conditioning (HVAC) systems that function independently from each other. Since the HVAC systems are separate, the annex is the subject of this report. The 1950 wing is the subject of a separate report.

Methods

Air tests for carbon dioxide, carbon monoxide, temperature and relative humidity with the TSI, Q-TRAK™ IAQ Monitor, Model 8551. Air tests for airborne particle matter with a diameter less than 2.5 micrometers were taken with the TSI, DUSTTRAK™ Aerosol Monitor Model 8520. Screening for total volatile organic compounds (TVOCs) was conducted using a Thermo Environmental Instruments Inc., Model 580 Series Photo Ionization Detector (PID).

Moisture content of porous building materials was measured with Delmhorst, BD-2000 Model, Moisture Detector with a Delmhorst Standard Probe.

Results

The school houses grades K through four, with a student population of approximately 540 and a staff of approximately 50. Tests were taken under normal operating conditions and results appear in Table 1.

Discussion

Ventilation

It can be seen from Table 1 that carbon dioxide levels were elevated above 800 parts per million parts of air (ppm) in four of thirteen areas surveyed, indicating adequate air exchange in most areas on the day of the assessment. However, it is important to note that several classrooms were unoccupied and/or had open windows, which can greatly reduce carbon dioxide levels.

Fresh air in classrooms is supplied by a unit ventilator (univent) system. Univents are designed to draw air from outdoors through a fresh air intake located on the exterior walls of the building (Picture 1) and return air through an air intake located at the base of each unit (Figure 1). Fresh and return air are mixed, filtered, heated and provided to classrooms through a fresh air diffuser located in the top of the unit. Univents were reported to be original equipment (approximately 50 years old), which can make them difficult to maintain/function due to unavailability of parts. The univent in classroom 21 was operating on "high"; however, the unit appeared to be operating at low capacity. Obstructions to airflow, such as papers and books stored on univents and bookcases, carts and desks in front of univent returns, were also seen (Picture 2). In order for univents to provide fresh air as designed, intakes must remain free of obstructions.

Exhaust ventilation in classrooms is provided by a mechanical exhaust system. The exhaust vents are located in the upper portions of coat closets and ducted to exhaust motors located on the roof. The location of these closet vents allows them to be easily blocked by stored materials.

To maximize air exchange, the BEHA recommends that both supply and exhaust ventilation operate continuously during periods of school occupancy. In order to have proper ventilation with a univent and exhaust system, the systems must be balanced to provide an adequate amount of fresh air to the interior of a room while removing stale air from the room. The date of the last balancing of these systems was not available at the time of the assessment. It is recommended that existing ventilation systems be re-balanced every five years to ensure adequate air systems function (SMACNA, 1994).

The Massachusetts Building Code requires a minimum ventilation rate of 15 cubic feet per minute (cfm) per occupant of fresh outside air or have openable windows in each room (SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week, based on a time-weighted average (OSHA, 1997).

The Department of Public Health uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches. For more information on carbon dioxide see Appendix A.

Temperature readings ranged from 70 ^{o} F to 77 ^{o} F, which were within the BEHA comfort guidelines. The BEHA recommends that indoor air temperatures be maintained in a range of 70 ^{o} F to 78 ^{o} F in order to provide for the comfort of building occupants. A number of temperature control/comfort complaints were expressed throughout the building, primarily that temperature was too high. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply. In addition, it is difficult to control temperature and maintain comfort without operating the ventilation equipment as designed (e.g., univents and exhaust vents obstructed).

The relative humidity ranged from 14 to 20 percent, which was below the BEHA recommended comfort range. The BEHA recommends a comfort range of 40 to 60 percent for indoor air relative humidity. Relative humidity would be expected to drop below comfort levels during the heating season. The sensation of dryness and irritation is common in a low relative humidity environment. Low relative humidity is a very common problem during the heating season in the northeast part of the United States.

Microbial/Moisture Concerns

In an effort to ascertain moisture content of water damaged materials within the annex, readings were taken in building materials that were most likely impacted by the ruptured univent heating coil. Building materials sampled included water damaged ceiling tiles and windowsills. Moisture readings from ceiling tiles and window frames in classrooms with no discernable water damage were measured for comparison. The Delmhorst probe is equipped with three lights as visual aids to determine moisture level. Readings, which activate the green light, indicate a sufficiently dry or low moisture level, those that activate the yellow light indicate borderline conditions and those that activate the red light indicate elevated moisture content.

Water damaged building materials beneath the ruptured heating coil did not have elevated moisture levels, indicating they had dried. Elevated moisture measurements were recorded in wooden windowsills in classroom 17 (Table 1/Picture 3), an area not affected by the ruptured heating coil. This measurement would indicate that the moisture dampening the windowsills could either be from high ambient relative humidity conditions or from moisture penetrating through the window system. It is important to note that moisture content of the annex building components was measured in real-time and is indicative of conditions present in the building at the time of the assessment. The building was evaluated on a sunny day, with an outdoor temperature of 56 ^{o} F and relative humidity of 20 percent. Prior to the assessment, the last measurable rain in the Bourne area was February 21, 2004, five days prior to the assessment date of February 26, 2004 (The Weather Underground, 2004). This means that classroom windowsills remained moist for an extended period of time. Moisture content may increase or decrease depending on building and weather conditions. For example, during the normal operation of a heating, ventilating and air-conditioning (HVAC) system, moisture is introduced into a building under conditions with high relative humidity. As indoor relative humidity levels increase, porous building materials can absorb moisture. Due to the low relative humidity measured indoors during the assessment, it is unlikely that the windowsills in classroom 17 were moistened from excessive ambient relative humidity.

Caulking around windows was missing/damaged in many areas (Picture 4). Water damaged wooden window frames and leaks were observed in several classrooms. Missing caulking and/or loose fitting window panes can make it difficult to control temperature and provide a means for water penetration into the building, leading to comfort complaints and/or water damage and subsequent microbial growth. Like other porous materials, wood that is wetted repeatedly can provide a medium for mold growth. Mold and related particulates can be irritating to sensitive individuals. In order for building materials to support mold growth, a source of moisture is necessary. Identification and elimination of water moistening building materials is necessary to control mold growth.

Interior and exterior wall cracks were observed (Pictures 5 and 6). Breaches in the building envelope can also provide a means for water penetration into the building. The US Environmental Protection Agency (US EPA) and the American Conference of Governmental Industrial Hygienists (ACGIH) recommends that porous materials be dried with fans and heating within 24-48 hours of becoming wet (US EPA, 2001; ACGIH, 1989). If porous materials are not dried within this time frame, mold growth may occur. Water-damaged porous materials cannot be adequately cleaned to remove mold growth. The application of a mildewcide to moldy porous materials is not recommended.

A number of classrooms had water-damaged ceiling tiles, which can indicate leaks from the roof or plumbing system. Water-damaged ceiling tiles can provide a growth medium for mold and should be replaced after a water leak is discovered and repaired.

Plants were noted in several classrooms. Plants can be a source of pollen and mold, which can be respiratory irritants for some individuals. Plants should be properly maintained and equipped with drip pans. Plants should also be located away from univents to prevent the aerosolization of dirt, pollen or mold.

Several subterranean pits were located along the perimeter of the building. These pits allow airflow into below grade air intakes for the mechanical ventilation system. Leaves, papers and other debris were observed on grating and the floor of the pits (Picture 7), which can also provide a source of mold growth. Mold odors and growth can subsequently be entrained into the ventilation system.

Other Concerns

Indoor air quality can be adversely impacted by the presence of respiratory irritants, such as products of combustion. The process of combustion produces a number of pollutants. Common combustion products include carbon monoxide, carbon dioxide, water vapor and smoke (fine airborne particle material). Of these materials, exposure to carbon monoxide and particulate matter with a diameter of 2.5 micrometers (μm) or less (PM2.5) can produce immediate, acute health effects upon exposure. To determine whether combustion products were present in the school environment, BEHA staff obtained measurements for carbon monoxide and PM2.5.

Several air quality standards have been established to address carbon monoxide pollution and prevent symptoms from exposure to these substances. The MDPH established a corrective action level concerning carbon monoxide in ice skating rinks that use fossil-fueled ice resurfacing equipment. If an operator of an indoor ice rink measures a carbon monoxide level over 30 ppm, taken 20 minutes after resurfacing within a rink, that operator must take actions of reduce carbon monoxide levels (MDPH, 1997).

ASHRAE has adopted the National Ambient-Air Quality Standards (NAAQS) as one set of criteria for assessing indoor air quality and monitoring of fresh air introduced by HVAC systems (ASHRAE, 1989). The NAAQS are standards established by the US EPA to protect the public health from six criteria pollutants, including carbon monoxide and particulate matter (US EPA, 2000). As recommended by ASHRAE, pollutant levels of fresh air introduced to a building should not exceed the NAAQS (ASHRAE, 1989). The NAAQS were adopted by reference in the Building Officials & Code Administrators (BOCA) National Mechanical Code of 1993 (BOCA, 1993), which is now an HVAC standard included in the Massachusetts State Building Code (SBBRS, 1997). According to the NAAQS established by the US EPA, carbon monoxide levels in outdoor air should not exceed 9 ppm in an eight-hour average (US EPA, 2000).

Carbon monoxide is a by-product of incomplete combustion of organic matter (e.g., gasoline, wood and tobacco). Exposure to carbon monoxide can produce immediate and acute health affects. *Carbon monoxide should not be present in a typical, indoor environment*. If it *is* present, indoor carbon monoxide levels should be less than or equal to outdoor levels. Outdoor carbon monoxide concentrations were non-detect or ND (Table 1). Carbon monoxide levels measured in the school were also ND.

The NAAQS originally established exposure limits for particulate matter with a diameter of 10 μm or less (PM10). According to the NAAQS, PM10 levels should not exceed 150 micrograms per cubic meter ($\mu g/m^3$) in a 24-hour average. This standard was adopted by both ASHRAE and BOCA. Since the issuance of the ASHRAE standard and BOCA Code, US EPA proposed a more protective standard for fine airborne particles. This more stringent, PM2.5 standard requires outdoor air particulate levels be maintained below 65 $\mu g/m^3$ over a 24-hour average. Although both the ASHRAE standard and BOCA Code adopted the PM10 standard for evaluating air quality, BEHA uses the more protective proposed PM2.5 standard for evaluating airborne particulate matter concentrations in the indoor environment. Outdoor PM2.5 concentrations were measured at 8 $\mu g/m^3$ (Table 1). PM2.5 levels measured indoors ranged from 8 to 12 $\mu g/m^3$. Although readings in several areas were above background, they were below the NAAQS of 65 $\mu g/m^3$. Frequently, indoor air levels of particulates (including PM2.5) can be at higher levels than those measured outdoors. A number of mechanical devices and/or activities that occur in schools can generate particulates during normal operation. Sources of indoor airborne particulates may include but are not limited to particles generated during the operation of fan belts in the HVAC system, cooking in the cafeteria stoves and microwave ovens; use of photocopiers, fax machines and computer printing devices, operating an ordinary vacuum cleaner and heavy foot traffic indoors.

Indoor air quality can also be impacted by the presence of materials containing volatile organic compounds (VOCs). VOCs are substances that have the ability to evaporate at room temperature. Frequently, exposure to low levels of total VOCs (TVOCs) may produce eye, nose, throat and/or respiratory irritation in some sensitive individuals. For example, chemicals evaporating from a paint can stored at room temperature would most likely contain VOCs. In an effort to determine whether VOCs were present in the building, air monitoring for TVOCs was conducted. Outdoor air samples were taken for comparison. Outdoor TVOC concentrations were non-detect (ND) (Table 1). Indoor TVOC measurements throughout the building were also ND.

Please note, TVOC air measurements are only reflective of the indoor air concentrations present at the time of sampling. Indoor air concentrations can be greatly impacted by the use TVOC containing products.

Several other conditions were noted during the assessment that can affect indoor air quality. A number of univents had accumulated dust, cobwebs and debris within the air handling chambers (Picture 8). Exhaust vents in coat closets were also coated with accumulated dust (Picture 9). In order to avoid this equipment serving as a source of aerosolized particulates, the surfaces of exhaust vents and the air handling sections of the univents should be regularly cleaned (e.g., during regular filter changes). Dust can be irritating to eyes, nose and respiratory tract.

Also of note was the amount of materials stored inside classrooms. In classrooms throughout the school, items were observed on windowsills, tabletops, counters, bookcases and desks. The large number of items stored in classrooms provides a source for dusts to accumulate. These items, (e.g., papers, folders, boxes) make it difficult for custodial staff to clean. Items should be relocated and/or be cleaned periodically to avoid excessive dust build up.

Cleaning products and unlabeled containers were found on countertops and beneath sinks in a number of classrooms (Picture 10). Cleaning products contain chemicals, which can be irritating to the eyes, nose and throat and should be stored properly and kept out of reach of students. In addition, bottles should be properly labeled in the case of an emergency.

In an effort to reduce noise from sliding chairs, tennis balls had been sliced open and placed on chair legs (Picture 11). Tennis balls are made of a number of materials that are a source of respiratory irritants. Constant wearing of tennis balls can produce fibers and allow VOCs to off-gas. Tennis balls are made with a natural rubber latex bladder, which becomes abraded when used as a chair leg pad. Use of tennis balls in this manner may introduce latex dust into the school environment. Some individuals are highly allergic to latex (e.g., spina bifida patients) (SBAA, 2001). It is recommended that the use of materials containing latex be limited in buildings to reduce the likelihood of symptoms in sensitive individuals (NIOSH, 1997). A question and answer sheet concerning latex allergy is attached as Appendix B (NIOSH, 1998).

Finally, several occupants had concerns of dirt and dust infiltration from road dirt that is reportedly deposited behind the annex building twice a year (Picture 12). Depending on wind and weather conditions this activity can generate airborne dust and debris that can be drawn into univents operating on this side of the building or through open classroom windows.

Conclusions/Recommendations

The conditions noted at the annex raise a number of indoor air quality issues. The combination of the general building conditions, maintenance, work hygiene practices and the condition of HVAC equipment, if considered individually, present conditions that could degrade indoor air quality. When combined, these conditions can serve to further negatively affect indoor air quality. Some of these conditions can be remedied by actions of building occupants. Other remediation efforts will require alteration to the building structure and equipment. For these reasons a two-phase approach is required, consisting of **short-term** measures to improve air quality and **long-term** measures that will require planning and resources to adequately address the overall indoor air quality concerns.

The following **short-term** measures should be considered for implementation:

1. Examine each univent for function. Survey classrooms for univent function to ascertain if an adequate air supply exists for each room. Consider consulting a heating, ventilation and air conditioning (HVAC) engineer concerning the calibration of univent fresh air control dampers throughout the school.
2. To maximize air exchange, the BEHA recommends that all ventilation systems that are operable throughout the building (e.g., gym, cafeteria, classrooms) operate continuously during periods of school occupancy independent of thermostat control. To increase airflow in classrooms, set univent controls to "high".
3. Remove all blockages from univents and exhaust vents to ensure adequate airflow.
4. Consider balancing mechanical ventilation systems every 5 years, as recommended by ventilation industrial standards (SMACNA, 1994).
5. For buildings in New England, periods of low relative humidity during the winter are often unavoidable. Therefore, scrupulous cleaning practices should be adopted to minimize common indoor air contaminants whose irritant effects can be enhanced when the relative humidity is low. To control for dusts, a high efficiency particulate arrestance (HEPA) filter equipped vacuum cleaner in conjunction with wet wiping of all surfaces is recommended. Avoid the use of feather dusters. Drinking water during the day can help ease some symptoms associated with a dry environment (throat and sinus irritations).

6. Seal window frames to prevent water penetration and further water damage. Replacement of chronically damaged wooden windowsills should be considered.
7. Ensure roof/plumbing leaks are repaired and replace any remaining water-stained ceiling tiles. Examine the area above and around these areas for mold growth. Disinfect areas of water leaks with an appropriate antimicrobial.
8. Remove leaves and debris from subterranean pits seasonally.
9. Move plants away from univents in classrooms. Avoid over-watering and examine drip pans periodically for mold growth. Disinfect with an appropriate antimicrobial where necessary.
10. Change filters for air-handling equipment as per the manufacturer's instructions or more frequently if needed. Vacuum interior of units prior to activation to prevent the aerosolization of dirt, dust and particulates. Ensure filters fit flush in their racks with no spaces in between allowing bypass of unfiltered air into the unit.
11. Clean exhaust vents periodically of accumulated dust.
12. Relocate or consider reducing the amount of materials stored in classrooms to allow for more thorough cleaning. Clean items regularly with a wet cloth or sponge to prevent excessive dust build-up.
13. Store cleaning products properly and out of reach of students. Ensure spray bottles are properly labeled in the event of an emergency.
14. Consider discontinuing the use of tennis balls on chairs to prevent latex dust generation.
15. Coordinate with Town and School officials to schedule delivery of dirt during non-occupied periods. If not feasible, notification should be made prior to delivery to ensure

airborne dirt and dust are not entrained into the building. This may entail temporarily deactivating univents and closing of classroom windows.

16. Consider developing a written notification system for building occupants to report indoor air quality issues/problems. Have these concerns relayed to the maintenance department/ building management in a manner to allow for a timely remediation of the problem.
17. In order to maintain a good indoor air quality environment on the building, consideration should be give to adopting the US EPA document, "Tools for Schools". This document can be downloaded from the Internet at http://www.epa.gov/iaq/schools/index.html.
18. For further building-wide evaluations and advice on maintaining public buildings, see the resource manual and other related indoor air quality documents located on the MDPH's website at http://www.state.ma.us/dph/beha/iaq/iaqhome.htm.

The following **long-term measures** should be considered:

1. Replace/repair window systems throughout the building-wide to prevent water penetration and drafts through window frames.
2. Based on the age, physical deterioration and availability of parts of the HVAC system, the BEHA strongly recommends that an HVAC engineering firm fully evaluate the ventilation system and its control system (e.g. pneumatic controls, air intake louvers, thermostats).

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Picture 1

Univent Fresh Air Intake

Picture 2

Classroom Univent Obstructed by Various Items

Picture 3

Elevated Moisture Content of Wooden Window Sill in Classroom 17

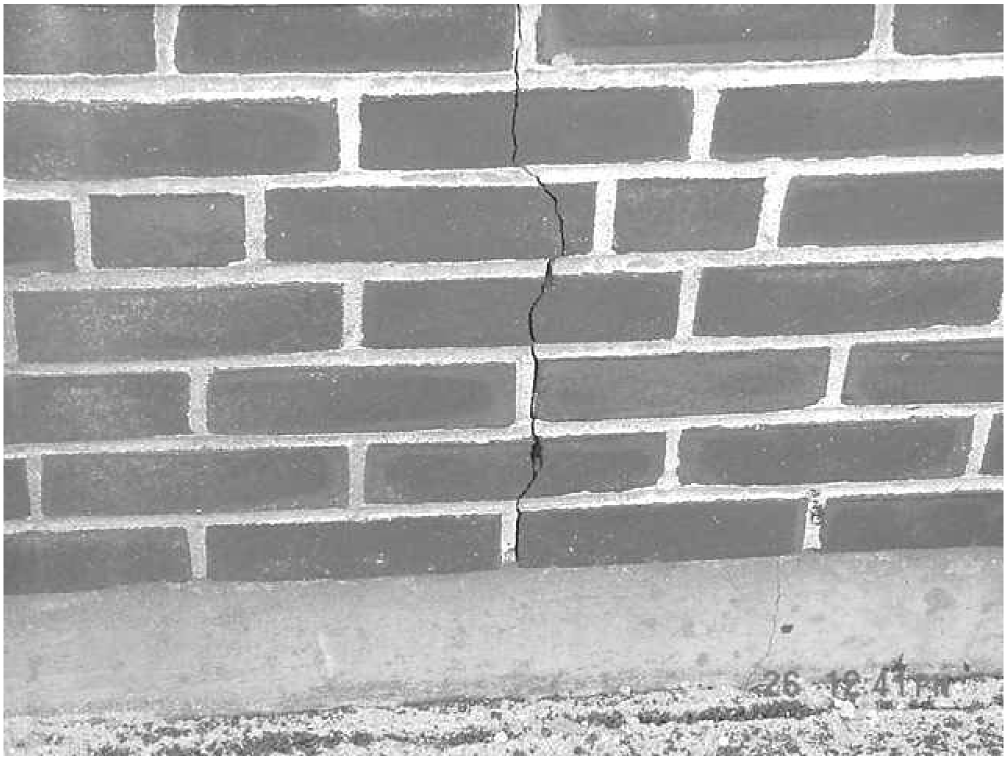
Picture 4

Missing/Damaged Window Caulking

Picture 5

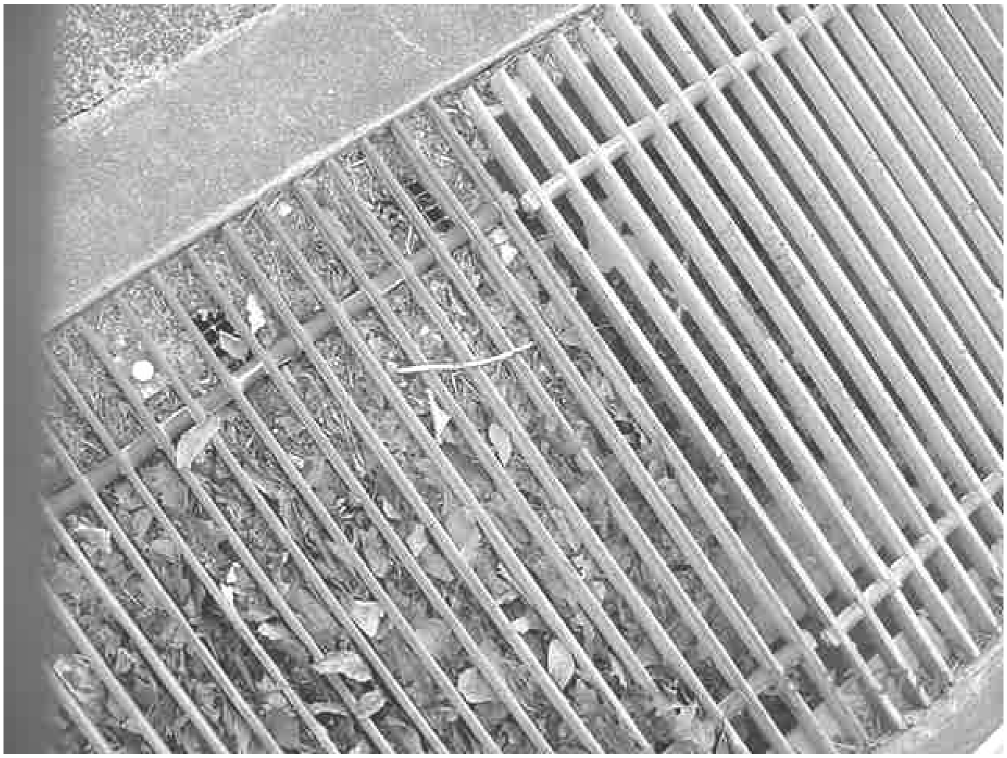
Interior Wall Crack

Picture 6



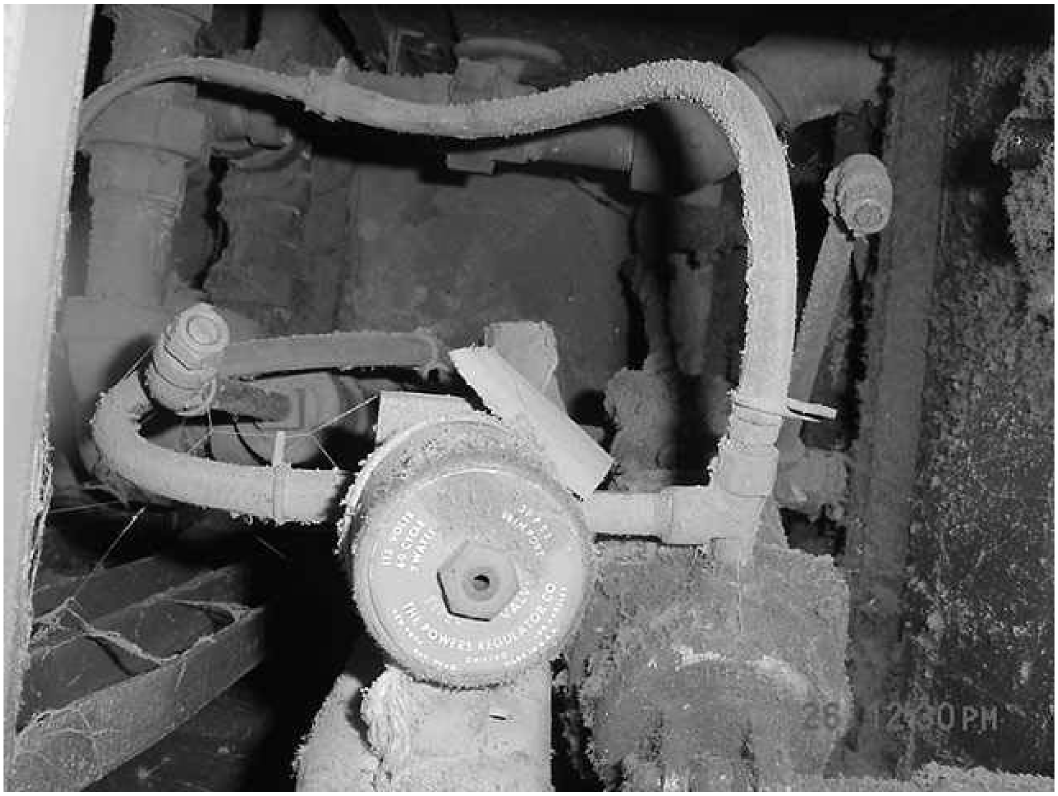
Exterior Wall Crack

Picture 7



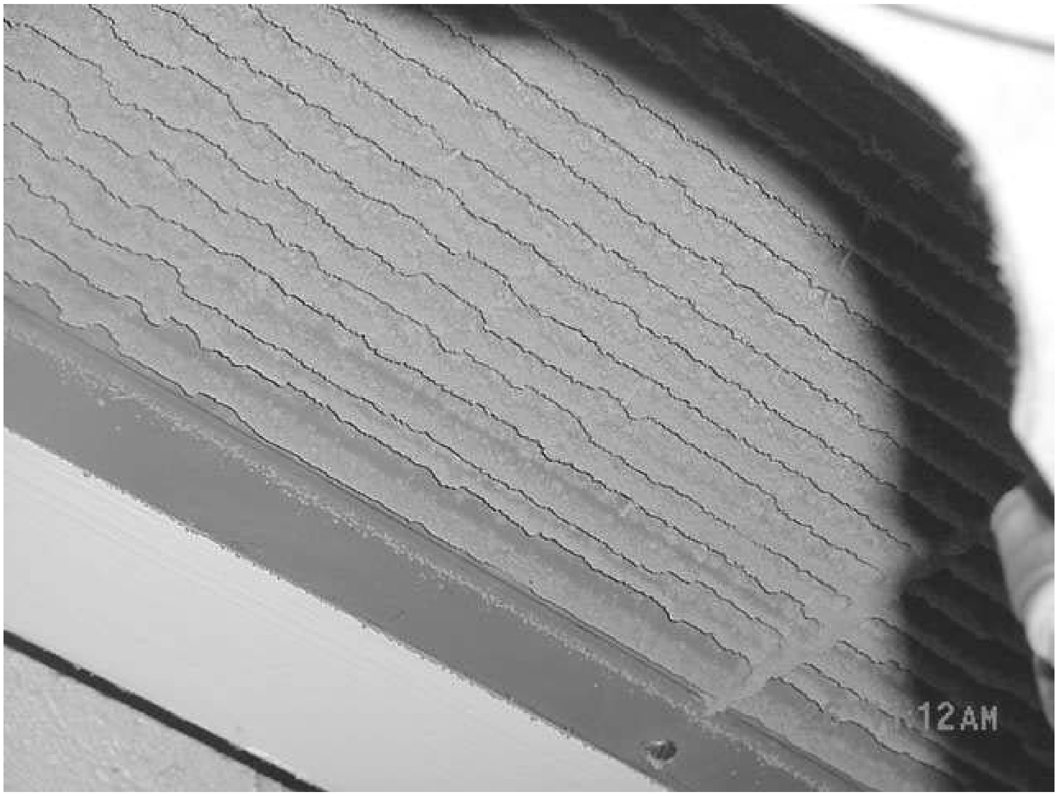
Leaves and Debris in Subterranean Air Intake Pit

Picture 8



Accumulated Dust in Univent Interior

Picture 9



Accumulated Dust on Closet Exhaust Vent

Picture 10

Spray Cleaning Products and Unlabeled Materials Under Sink in Classroom

Picture 11

Tennis Balls on Bottoms on Chairs and Desks

Picture 12

Lot Area Where Road Dirt is Reportedly Emptied, Picture Taken From Inside Classroom

Peebles Elementary School Annex

70 Trowbridge Road, Bourne, MA

Table 1

Indoor Air Results

February 26, 2004

Location/ Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (*ppm)	Carbon Monoxide (*ppm)	TVOCs (*ppm)	PM2.5 (µg/m3)	Occupants in Room	Windows Openable	Ventilation		Remarks
									Supply	Exhaust	
Background (outdoors)	56	20	376	ND	ND	8			-	-	Clear skies, sunshine, NE winds 5-10 mph
21	70	19	856	ND	ND	10	19	Y	Y	Y	Window open, UV-high but operating at low capacity, DO, 25+ CT, area carpet, card board boxes under sink, cleaning products/unlabeled bottles, empty cans/milk cartons
22	77	16	717	ND	ND	11	1	Y	Y	Y	20+ CT, 22 occupants gone 10 min
25	74	16	764	ND	ND	11	22	Y	Y	Y	20+ CT, CD
24	72	14	484	ND	ND	8	0	Y	Y	Y	20+ CT, window open
23	71	15	624	ND	ND	10	22	Y	Y	Y	Window open, MT, plans, 20+ CT, UV-blocked

ppm = parts per million parts of air
µg/m3 = microgram per cubic meter
WD = water damage(d)
AD = air deodorizer
AP = air purifier

CD = chalk dust
DEM = dry erase marker
DO = door open
ND = non detect
PC = photocopier

PF = personal fan
TB = tennis balls
UF = upholstered furniture
UV = univent
CT = ceiling tile
MT/AT = missing tile/ajar tile

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred
	600 - 800 ppm = acceptable
	> 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

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									Supply	Exhaust	
20	71	18	874	ND	ND	9	25	Y	Y	Y	20+ CT, DO
Library	71	18	942	ND	ND	11	0	N	Y	Y	
15	74	20	942	ND	ND	9	0	Y	Y	Y	MTs, 20+ CT, low moist content wood cab & sinks
16	71	18	798	ND	ND	11	25	Y	Y	Y	20+ CT, TB, dusty vents, leaking sink, UV-blocked, cleaning products on countertops, accumulated items
14	73	18	670	ND	ND	9	20	Y	Y	Y	DEM
17	71	18	782	ND	ND	11	3	Y	Y	Y	24 occupants gone 5 min, 15+ CT, low moist content CT, elevated moist content wooden window sills-water damage, window leaks reported

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									Supply	Exhaust	
18	70	17	640	ND	ND	12	27	Y	Y	Y	Window open, accumulated items, dusty vents, UV-blocked, window leaks reported, wall cracks, cleaning products on floor, TB, temp control complaints, low moist content CT and wood
19	70	19	634	ND	ND	8	4	Y	Y	Y	Wood windowsill-dry rot, low moisture content
14								Y	Y	Y	Missing UV (side) panel-drawing dust/cobwebs from wall cavity

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